

CHOICE OF ANIMAL COMPONENTS OF CLOSED ECOLOGICAL SYSTEMS

N. V. Mironova

As components of closed ecological systems various authors [1, 5, 9, 10] have suggested crustaceans, mollusks, fishes, hens, rabbits and goats. /486

During the study of the provision of a balanced human diet during long space flights the question of incorporation of vertebrates in the food cycles naturally arises, for this would provide man with essential and first-class proteins, fats and other food substances and, at the same time, give a diet to which he is accustomed.

There are few reports in the literature dealing with the inclusion of fish in a closed ecological system [14].

As components of a closed ecological system under spacecraft conditions fishes possess many advantages. They can be used almost entirely as food, because their body does not contain indigestible keratinous or chitinous parts. Fish also have very high food value and very acceptable taste properties. /487

For these reasons the possibility must be examined that among fishes species can be chosen which are capable of existing and propagating in small containers under stipulated temperature conditions (a wide range being desirable), and not too fastidious with respect to oxygen content and other qualities of the water (pollution, pH, etc.).

Finally, a most important condition is the possibility that the selected species can be introduced between preceding and succeeding links in the food chain, i. e., the ability of this species to utilize organic matter of mainly vegetable origin, unsuitable as human food (unicellular algae, green mass of higher plants), on the one hand, and its suitability as human food on the other hand.

The next stage in the study of this problem must be to establish quantitative indices for consumption and production; to study the ability of the species to give a rapid, considerable and uniform increase in biomass from a unit volume and unit weight of food. After preliminary choice of test object on the basis of general data concerning the biology of the species, the primary research program can be planned as follows:

- 1) The study of the limits of food adaptability of the chosen object, its ability to utilize green mass of lower and higher plants and to grow on such a diet;
- 2) The study of quantitative food requirements depending on its composition and the age of the investigated organisms;
- 3) The study of the rate of its increase in weight;

4) The study of special features and rate of reproduction;

/488

5) The obtaining of data for the rate of increase of population and of the total biomass of the population.

The difficulty in choosing an object satisfying all the demands made on components of a closed ecological system will be obvious. For this reason, several species must be investigated.

At the present time the species corresponding most fully to the presented demands is the tropical fish known as the tilapia (Tilapia mossambica Peters) belonging to the Cichlidae family. This conclusion is based on the following properties of this species:

1. High ecological plasticity.
2. Omnivorous and mainly phytophagous feeding habits. Ability to feed on algae, green mass of higher plants, and animals.
3. A supposed ability to feed on Chlorella.
4. A technically convenient optimum temperature of existence of between 20 and 28°, not requiring special thermoregulatory devices for its maintenance.
5. Resistance to changes in temperature over a wide range (from +8 - 10° to nearly 40°).
6. Absence of demand of seasonal changes in temperature conditions.
7. Absence of seasonal cyclic pattern of growth and reproduction (with consequent regular increase in biomass).
8. Early maturation, frequent spawning all the year round, caring for offspring, rapid increase in population of biomass.
9. High rate of growth at an early age and attainment of suitable dimensions for consumption as food within a few months.
10. Ability to exist in a high stocking density without appreciable influence on growth and propagation, reported in the literature [12].

From the properties of Tilapia mossambica Peters listed above, it appears likely that a uniform increase in proteins may be obtained throughout the year by keeping this species under constant conditions of existence.

/489

It must be added to these remarks that analysis of the relative weights of different parts of the tilapia body (Table 1) showed that even in tilapia fry the weight of meat and skin as a percentage of the live body weight is very similar to that of the carp, amur, silver carp and bighead.

TABLE 1. Relative Weights of Various Parts of the Body of Fishes (in % of Live Weight)*

Species	Sex	Number of specimens	Weight of fish, in g	Head	Viscera	Fins and bones	Meat and skin	Scales	Total	Loss of blood and moisture	Remarks
Tilapia. . . .	♂	1	130,35	19,64	11,43	17,72	43,54	3,49	95,82	4,18	Dissected raw fishes
"	♀	1	62,9	18,84	8,82	16,38	46,02	4,06	94,12	5,88	
"	♂	1	126,2	18,34	4,91	9,51	52,02	4,52	89,30	10,70	Dissected cooked fishes
"	♀	1	66,85	18,48	6,73	10,92	49,53	4,26	89,98	10,02	
"	juv	5	18,7	20,05	8,13	11,76	53,48		93,42	6,58	"
Carp.	?	?	428	16,9	12,1	14,1	52,4	4,5	100,0	—	According to Sukhoverkhov[4]
White amur.	?	?	794	13,4	9,4	12,4	61,2	3,6	100,0	—	
Silver carp	?	?	449	17,0	10,6	12,4	55,6	4,4	100,0	—	
Big head. . .	?	?	703	23,2	7,6	14,6	51,1	3,5	100,0	—	

*The weight of blood and moisture lost during dissection is not distinguished in the data cited from the literature. In our results they are shown in a separate column. If this amount is added to the weight of meat, the results obtained are identical to those characteristic of the carp, while amur, silver carp and bighead.

Commas represent decimal points.

CONDITIONS OF EXISTENCE OF EXPERIMENTAL FISH

Special experiments to determine the tolerance limits of tilapia to temperature and content of oxygen and organic substances in water were not undertaken. However, the water temperature in the aquaria was recorded twice a day; in addition, samples of water from aquaria with different densities of stocking were analyzed hydrochemically, in the morning before cleaning the aquaria (at the moment of worst pollution of the water by decomposition products of excreta) and at the end of the day (after changing the water and introduction of food into the aquaria). The fluctuations in temperature and chemical properties of the water thus discovered to some extent indicate changes in external environmental factors tolerated by tilapia (Table 2).

TABLE 2. Fluctuations in Conditions of Existence of Tilapia in Experimental Aquaria*

Indices	Minimum	Maximum
Water temperature.	17,9	37,6
Mean water temperature for the month	20,7	27,3
Fluctuations in water temperature during month.	1,0	17,5
Fluctuations in water temperature during day	0,0	17,5
pH.	<6,0	6,8
Oxygen concentration in water, mg/liter.	0,85	8,37
Oxygen saturation of water, %.	9,6	94,5
B. O. D. (permanganate)	11,8	17,3
B. O. D. (bichromate)	23,2	67,2

*The hydrochemical analyses were performed by N. F. Smirnova, Hydrochemist in the Laboratory of Freshwater and Experimental Hydrobiology, AIN, USSR Academy of Sciences.

Commas represent decimal points.

A factor limiting the distribution of tilapia, including *Tilapia mossambica* under natural conditions is the winter water temperature [13]. A temperature of 8° is lethal for this species [6, 12].

/490

As the results in Table 2 show, in our experiment the tilapia lived in a mean temperature of 20.7-27.3°. However, in some aquaria without special heating of the water, at certain periods the temperature fell to 17.9°; in some cases it rose for a short time to 30, 34 and 37.6°. As a rule the diurnal fluctuations of temperature did not exceed 2-3°.

The oxygen concentration in the water was comparatively small, varying in different aquaria from 0.85 to 8.37 mg/liter, and the percentage saturation varied from 9.6 to 94.5. In half the cases mentioned the oxygen concentration in the water was below 2 mg/liter and the percentage saturation was below 50, while in one-third of cases it was below 20. The fish were kept in aquaria made of organic glass, 40 liters in capacity excluding soil and plants.

The limits of stocking density were not studied. Up to 200 specimens of 2-month-old fry and up to 70 specimens of 10- to 12-months-old fish were kept in the

aquaria. The maximal total live weight of fish per 40 liters water was 1408 g, i. e., 35.2 g/liter water.

NUTRITION

According to reports in the literature, Tilapia mossambica is extremely accommodating as regards food and under natural conditions will eat both animal and plant food. It lives on phytoplankton, filamentous algae, green mass of algae and higher aquatic plants, zooplankton, worms, insects and their larvae, tiny shrimps and other crustaceans [7, 12]. In aquaria and ponds it readily eats white bread, chopped meat and fish, mollusks, oat flakes, oat and corn flour, all types of scraps and oil cake, grain, rice, beans, soybeans, pressed coconut, green mass of various plants, and kitchen waste.

In 1963 we carried out investigations to study the ability of tilapia to feed on green particles of higher land plants of different families and differences in their increase in weight when fed in this way by comparison with fish receiving animal food (mainly moths).

Initially all the tilapias received food usually given the fish in aquaria—midge larvae, tubifex, living and, in very small amounts dried, water fleas. Fry obtained in the laboratory were fed on infusorians, vinegar eelworms, and water fleas, followed by small tubifex, larger tubifex, cut-up midge larvae and, finally, intact and large midge larvae. In 1964 the fry were given a simpler diet. In the early stages (until one month) the young fish received vinegar eelworms and after the 1st-14th day, ground midge larvae together with ground sorrel after the 10th-20th day. Later, they received cut-up, followed by whole midge larvae or unchopped green matter. In addition, the larvae and young fish received Chlorella as a suspension of living cells. The fact that the larvae ate the Chlorella cells was proved by examination of the excreta and intestinal contents, but it is of course impossible to estimate this consumption quantitatively and, still less, to observe it directly. /491

Some of the experimental fish were used to study their ability to eat plant food, to determine which plants were preserved and which were rejected, and to make observations on changes in the rate of growth on such a diet. For a period of 6 months (from the age of 8 to 14 months) these fishes received a varied diet in which the proportion of animal food was gradually reduced and the proportion of plant food increased. After 70 days, animal food was completely excluded from the diet. In two aquaria no midge larvae whatever were given for 113 days.

During the experiment the ability of tilapias to eat 12 species of plants belonging to the families Polygonaceae, Chenopodiaceae, Umbelliferae, Caryophyllaceae, Cruciferae and Cucurbitaceae was investigated. The fish were given green leaves of sorrel, rhubarb, beetroot, two species of orache, carrot, chickweed, cabbage, cauliflower, radish, lettuce and vegetable marrow. All these plants were eaten completely by the fish, but not with the same avidity. Sorrel and rhubarb were eaten with preference, and carrot leaves least avidly. The harder and more solid parts of plants were eaten badly (the stems, the leaf veins). In an analogous experiment, Bishai [8] kept tilapia on Leguminaceae (Vicia faba L.).

TABLE 3. 24-Hour Index for Tilapias of Different Ages

Aquarium No.	Age, months									
	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-11	11-12
1L ₅	25	18	11	11	6,0	5,5	5,7	4,4	3,4	2,9
2L ₅	26	16	10	9	6,8	5,6	5,7	4,9	3,8	3,5
L ₁₀	11	18	12	11	6,4	5,0	5,0	3,6	3,5	3,6
L _{5a}	25	22	11	5,0	5,0	4,5	3,6	4,0	3,3	2,7
L _{10a}	24	18	10	6,0	—	4,2	5,5	4,9	3,6	3,5
Mean	22,2	18,4	10,8	8,4	6,0	4,9	5,1	4,3	3,5	3,2

Commas represent decimal points.

Because all the plants suggested without exception were eaten, it can be hoped that tilapia will prove capable of being fed on the green mass of plants which will be included as components of the closed ecological system.

/492

The food given to the fish was analyzed quantitatively starting from the time when they reach the age of about 1 month. Before this age the larvae and young fish were fed on infusorians and vinegar eelworms, which cannot be analyzed gravimetrically.

By weighing the fish every month, the quantity of food required per unit body weight of tilapias of different ages per day can be calculated (as a mean value per month). This quantity, expressed as a percentage, is known as the 24-hour index. Data for the 24-hour index for tilapias of different ages and on different diets are given in Table 3. As this table shows, the 24-hour index for tilapia decreases with age. If animal food is given, the 24-hour index between the ages of 2 and 3 months is 22, between 3 and 4 months 18, from 5 to 6 months its value has fallen to 8, and after 9 months it does not exceed 5. If tilapias aged 10-13 months are fed on plant food only, the 24-hour index varies between 10 and 20.

The mean monthly food indices, expressing the ratio between the weight of food eaten and the increase in body weight of the fish, are given in Table 4. The food index for fish aged 2-3 months fed on an animal diet varies from 2.8 to 10.1 with a mean value of 6.5. This means that for every 6.5 g of food eaten, the fish gains 1 g body weight. The food index for the fish aged 9 months has a mean value of 10.

If the fish are transferred to a plant diet, consisting of plants to which they are unaccustomed, the food index rises appreciably. For fish (aged from 10 to 13 months) receiving a plant diet exclusively, the mean food index varied from 58 to 92. Much better indices of food utilization relative to growth were obtained for fish receiving mixed diet, in which various plants were supplemented by from 20 to 60% of midge larvae. The food index for these fish varied from 58 to 27 respectively.

/493

TABLE 4. Food Index of Tilapias of Different Ages

Aquarium No.	Age, months									
	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-11	11-12
1L ₅	6,8	7,4	8,9	8,8	6,0	8,4	6,2	10,5	19,5	12,0
2L ₅	7,6	8,5	10,6	10,7	5,6	6,8	8,4	10,3	16,4	10,0
L ₁₀	2,8	8,6	7,4	12,8	5,9	7,1	9,9	9,4	23,6	9,5
L _{5a}	5,2	7,2	8,7	6,5	6,7	8,3	10,7	10,9	11,0	12,8
L _{10a}	10,1	8,2	8,0	6,0		7,9	—	11,0	11,3	10,4
Mean	6,5	8,0	8,7	8,9	6,0	7,7	8,8	10,4	16,3	10,9

Commas represent decimal points.

GROWTH

All the experimental fishes starting from the age of 2 months were measured and weighed every month. In this way data were obtained for their mean length, mean weight and increase in these parameters for each month of life.

Before describing the results showing the rate of growth in weight of the tilapias in the aquaria, it should be emphasized that the gain in weight and size cannot in any way be regarded as the maximum possible. In the series of experiments undertaken, no attempt was made to obtain maximum increase by the use of complex diets and by increasing the qualitative value of the diet. On the contrary, the fish were deliberately kept under unfavorable nutritional conditions in order to determine their tolerance, and their adaptability and potential ability to grow when fed on a monotonous diet quite out of keeping with natural conditions. Subsequent investigations will be carried out to investigate ways of keeping and feeding tilapias in order to obtain the maximum increase in weight.

In his monograph on the biology and cultivation of tilapia, Chimitz [11, 12] cites the following limiting dimensions and weight of *T. mossambica*: 38-39 cm and 700-850 g. There are also reports that individuals of this species have attained even larger sizes.

/494

In connection with the present problem, the weight and rate of growth of the fry are interesting, because the long-term rearing of fish during space flights may not be economic. It is therefore important to know as far as possible ahead when the fish will reach a size suitable for use as food.

Data showing the gain in weight of tilapias for each month of life during the first year as a percentage of their weight at the age of 12 months are given in Table 5. This table shows that most of the body weight attained by 12 months of age is formed between the third and 10th months. After 10 months the gain in weight falls slightly.

TABLE 5. Growth of Tilapias per Month as Percentages of their Weight at the age of 12 Months
(Results obtained in 1963)

Aquarium No.	No. of specimens	Months										
		0-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-11	11-12
1L ₅	6	2,2	5,1	8,9	8,2	9,1	14,2	9,7	19,4	10,6	4,8	7,2
2L ₅	6	2,2	6,1	7,2	5,2	9,3	13,2	12,8	13,7	14,1	5,8	10,6
L ₁₀	6	1,7	5,5	6,7	9,3	12,3	14,4	14,2	11,2	9,5	3,7	11,0
L _{10a}	6	2,0	8,6	10,6	11,0	12,6	11,0	11,4	3,9	10,3	8,5	9,7
L _{5a}	12	1,9	6,3	15,0	11,2	10,9	12,0	10,7	7,5	9,6	8,0	6,4
Mean	18	2,0	6,3	9,7	8,9	10,8	12,9	11,7	11,1	10,8	6,1	9,0

Commas represent decimal points.

TABLE 6. Mean Length of Tilapias of Different Ages (in mm)

Aquarium No.	Age, months										
	2	3	4	5	6	7	8	9	10	11	12
1L ₅	41	62	80	96	110	121	130	142	151	156	160
2L ₅	41	64	81	91	99	116	128	138	146	153	159
L ₁₀	39	64	81	101	111	133	144	152	159	162	166
L _{5a}	40	66	89	103	113	125	131	139	143	147	152
L _{10a}	41	66	84	96	109	—	126	131	136	142	148
Mean	40,4	64,4	83,0	97,4	108,4	124,0	131,8	140,4	147,0	152,0	155,8

Commas represent decimal points.

The mean length and mean weight of tilapias month by month are given in Tables 6 and 7. The mean weight of tilapias receiving an animal diet increased from 1.2 g at the age of two months to 60 g at the age of 12 months. In experiments carried out in 1963 in which tilapias received plant food and their rate of growth was studied, fish were investigated between the ages of 8 and 14 months. The results of these experiments are described in our previous paper (N. V. Mironova, see this collection). As mentioned above, fish receiving an animal diet grew more intensively than fish receiving a vegetable diet.

/495

TABLE 7. Mean Weight (in g) of Tilapias of Different Ages

Aquarium No.	Age, months										
	2	3	4	5	6	7	8	9	10	11	12
1L ₅	1,4	4,6	10,2	15,5	22,6	30,0	36,1	48,2	54,8	57,9	62,4
2L ₅	1,4	5,1	9,6	12,8	16,6	26,6	34,5	42,9	49,3	55,1	61,6
L ₁₀	1,3	5,6	10,7	17,8	23,4	38,2	49,0	57,5	64,8	67,7	76,1
L _{5a}	1,0	5,3	12,6	18,7	24,6	31,1	36,9	41,0	45,7	50,5	54,0
L _{10a}	1,1	5,4	10,3	16,2	22,5	—	33,7	35,6	40,6	44,9	49,7
Mean	1,2	5,2	10,7	16,2	21,9	31,5	38,0	45,0	51,0	55,2	60,7

Commas represent decimal points.

Males and females grow equally until the age of 8-9 months. Thereafter, females begin to lag behind males appreciably in growth. Differences in weight and length increase with age. The mean weight of males aged 12 months in the aquaria was 67.7 g, compared with 47.7 g for females. The maximal weight reached by one male at the age of 27 months was 227 g.

REPRODUCTION

Tilapia mossambica Peters is a species in which the female incubates the eggs in her mouth. In the extensive literature on the biology of tilapia there are many reports of the necessity of a sandy soil for successful spawning of these fish, in which they dig a nest for laying the eggs. In our laboratory, spawning and subsequent incubation of the eggs took place successfully not only in aquaria with soil and vegetable matter, but also in 40-liter organic glass aquaria without soil or plants, and in groups of 4 or more fish.

The age of the females at the first spawning varies from 5 to 7 months (Table 8). Their weight ranges from 2.5 to 13.5 g and their length from 65 to 90 mm (mean 9.5 g and 83 mm). The frequency of reproduction varies from some females to others. On the average for the year for six females the interval between spawning was 40 days. It was much shorter for some females. For instance, for one female which spawned 11 times from March 16 to November 1, the mean interval over this period was only 20 days, varying from 17 to 26 days; by February this fish had spawned twice again and the mean interval had increased to 25 days. The minimal observed interval from one spawning to the next was 16 days. Reproduction took place during every month from February to January inclusive.

It is difficult to judge the fertility of the tilapias, because the eggs which have been laid are taken by the female into her mouth immediately after fertilization. However, it is possible to judge at least their minimal fertility from the number of fry reared from individual spawnings. A case was recorded when a female weighing 25 g laid 184 eggs; from a female weighing 30 g 209 young fish

were counted. In the ovaries of a female weighing 34 g, 339 eggs were found. In the ovaries of a female weighing 46.5 g 400 large eggs and 629 small eggs were found.

TABLE 8. Reproduction in Six Female Tilapias from February 18, 1963 to February 10, 1964

Indices	No. of females					
	5/12	10	8 ₁	5 ₂	8 ₂	4
No. of spawnings	13	8	9	9	6	3
Age at first spawning, months.	6	6	5	6	5	7
Weight, g	11	11	10	9	2,5	13,5
Length, mm	88	90	82	—	65	90
Mean interval between spawnings, days	25	41	44	38	71	60
t ^o min at time of spawning.	21,6	22,2	23,5	22,5	22,2	22,5
t ^o max at time of spawning	26,5	25,9	26,4	27,7	25,1	28,7
t ^o mean at time of spawning	23,9	24,2	24,8	24,8	23,5	26,1
t ^o mean during incubation.	24,1	24,9	25,0	24,1	24,0	26,1
Mean incubation time, days	11	11	11	9	9	—
Fertility.	90, 77 и >30	25, 60, 209, 20 & 41	31, 15, 184 & 70	102, 97 & 149	70 & 40	—
Number of larvae reared	90 & 77	60 & 209	—	—	—	—
Number surviving six months	42 & 77	14 & 204	—	—	—	—

Commas represent decimal points.

The duration of embryonic development until hatching of the larvae from the eggs was six days at a temperature of 23°. The duration of rearing of the eggs and larvae by the female (from spawning until liberation of actively swimming larvae with absorbed yolk sac) averaged 10 days.

/496

Spawning took place at temperatures between 21.6 and 28.7°, with a mean value of 24.4°.

For each incubation period the mean water temperature was calculated on the basis of two measurements during the day. The mean temperature for all incubation periods was 24.5°, but it varied in individual cases from 21.9 to 28.6°.

In 1963 young fish were reared in the laboratory from four layings of eggs. The number of fry in these layings was 90, 60, 77 and 209 fish. In the first case some of the fry died during the first month of life because of a breakdown in the air supply. In the second laying cases of disease were observed among the fry. The fry from the 3rd and 4th spawnings and fry reared in 1964 gave a survival rate of 100%.

The potential ability of the tilapia to increase its population rapidly can be judged from the pattern of its reproduction and the high rate of survival of its young.

/497

On the basis of the demands made on the animal components of the ecological system which were listed in the introduction the following preliminary assessment of the tilapia can be made.

1. With respect to the percentage of meat contained in its body the tilapia is close to other species of fish including the carp.
2. The tilapia is tolerant with respect to the conditions of its existence and, judging from the results obtained, it can live at a high stocking density, and under the stipulated temperature and oxygen conditions.
3. The tilapia can utilize a wide range of food products, both animal and plant. It readily eats the green parts of various vegetable plants, and thus satisfied one of the principal requirements.

Because of its frequent reproduction, the tilapia can quickly and regularly increase its population. Because of the comparatively high rate of growth, there are good grounds for expecting that this species can provide an adequate rate of increase of the total biomass of the population.

From the foregoing remarks it can be concluded that Tilapia mossambica Peters is a promising species for future research for the purpose of introducing it as a component in the closed ecological system.

REFERENCES

1. Akhlebinskiy, I.S., V.P. Bychkov, I.A. Il'ina, Yu. I. Kondrat'yev and A.S. Ushakov.: Sb. Problemy kosmicheskoy biologii [In: Problems in Space Biology], Vol. 1, 1962, p. 145.
2. Mironova, N.V.: Dokl. Akad. Nauk SSSR, Vol. 165, 5, p. 1179, 1965.
3. Idem.: Ibid., Vol. 166, 4, p. 968, 1966.
4. Sukhoverkhov, F.M.: Sb. Problemy rybokhozyaystvennogo ispol'zovaniya rastitel'noyadnykh ryb v vodoyemakh SSSR [In: Problems in the Use of Phytophagous Fish for Fish Breeding Purposes in Water Systems of the USSR], Turkmenian SSR Acad. Sci. Press, Ashkhabad, 1963, p. 48.
5. Ushakov, A.S. and V.P. Bychkov.: Sb. Problemy kosmicheskoy biologii [In: Problems in Space Biology], Vol. 2, 1962, p. 48.

6. Chang Kong Tam.: Sb. dokladov na 2-m plenumе komissii po rybokhozyay-strennomu issledovaniyu zapadnoy chasti Tikhogo okeana [Collected Proceedings of the Second Plenum of the Commission on Fisheries Research in the Western Part of the Pacific Ocean]. Moscow, Pishchepromizdat, 1962, p. 225.
7. Atz, J.W.: Animal Kingdom, Vol. 57, p. 148, 1954.
8. Bishai, H.M.: Hydrobiologiya, Vol. 20, p. 31, 1962.
9. Brockman, M.G., A.S. Henick, G.W. Kurtz and R.G. Tischer.: Food Technol., Vol. 12, p. 449, 1958.
10. Chimitz, P.: FAO Fish. Bull., Vol. 8, p. 1, 1955.
11. Idem.: Ibid., Vol. 10, p. 1, 1957.
12. Koura, R. and A.K. Bolock.: Egypt. Hydrobiol. Dept. Inst. Freshwater Biol. Notes and Memoirs, Vol. 41, 1, 1958.
13. Lorant, M.: Food Manufacture, Vol. 34, 479, 1959.
14. Nakamura, H.: Japan. Astronaut. Soc., 1, 1959.